# OBSERVATIONS OF SEA SURFACE TEMPERATURE AND WINDS ASSOCIATED WITH FLORIDA, USA, RED TIDES (*GYMNODINIUM BREVE* BLOOMS)

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## ABSTRACT

*Gymnodinium breve* blooms on the west coast of Florida USA occur from summer to winter, and most frequently in the fall. The change in bloom occurrence correlates to seasonal variations in the wind and sea surface temperature.Blooms typically initiate offshore in the summer, when the winds are weakest. However, they appear at the coast and continue during the fall, a period of strong easterly (offshore) winds. During the winter, the water cools beginning at the coast and spreading offshore, gradually making conditions nearshore less favorable for bloom maintenance. The winds weaken during the same time. Weak winds and warm temperatures in the summer probably encourage bloom initiation by allowing concentration of organisms near surface. Stronger winds in the fall may help in the redistribution of the organism to the coast, but falling temperatures in the winter may make conditions less suitable for bloom maintenance. Rare winter blooms may be introduced by other circulation features such as filaments from the Loop Current.

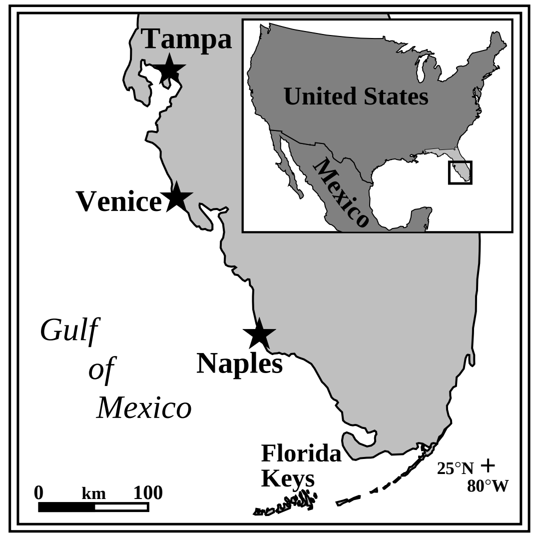


Fig. 1. Location of Florida West Coast and stations.

## INTRODUCTION

Blooms of *Gymnodinium breve* off Florida are commonly initiated during the summer but rarely in the winter [1,2]. The blooms are least common at the coast in late winter and spring, although anomalous major blooms occurred in winter, 1982 and 1996. Previous work has shown an association of blooms with frontal boundaries caused by Loop Current waters impinging on the west Florida shelf [1,2]. Wind and water temperature may be critical in controlling blooms; upwelling [1], surface drift [3], and seasonal cooling may control the extent of the blooms.

The linkage of temperature and winds with the seasonal variations in the west Florida red tides has not been investigated previously, although lack of growth at low temperatures certainly controls the distribution [2]. A combination of data sets can be used to assess the climatological factors causing red tides. We compare reports of *G. breve* blooms immediately at the coast (as distinguished from blooms reported offshore, as offshore records are limited) with winds over the past 35 years, and water temperature from satellite imagery and coastal instruments over seven years to identify climatological linkages in the seasonal occurrence of red tide.

## METHODS

The state of Florida documents the occurrence and cell concentration of red tide for public health. This record includes samples from onshore and from cruises offshore extending back 35 years. The offshore data set is incomplete as cruises are not frequent enough to detect the existence of blooms in all months (or years). Blooms tend to remain onshore for long periods, generally over a month, and the data set has been summarized to identify the presence of bloom concentrations of > 5000 cells/L. While blooms only a few kilometers offshore may cause problems such as fish kills, we have included only blooms present at the coast extending from Tampa to Naples (Fig. 1)

Hourly winds at Tampa international airport between 1961 and 1996 were obtained from the National Climatic Data Center. Monthly mean wind vectors were computed as means of 3-day low pass filtered hourly winds. These are presented in oceanographic direction (toward which the wind is blowing). Principal axes of variance were also constructed. Lengths of the axes are the square root of the eigenvalues of the covariance tensors [4]. The principal axes can be used to describe both the sub-monthly variability (isotropic or anisotropic) and the direction of preferred variability. Hourly water temperature from the C-MAN (Coastal meteorological automated network) station at Venice, Florida, were obtained from the National Data Buoy Center.

The satellite imagery derives from the advanced very high resolution radiometer (AVHRR) on the US polar-orbiting environmental satellites. The primary data set comes from the satellites having a nominal overpass time of 1:30 PM, NOAA-14 (after December 1994) and NOAA-11 (prior to October 1994). The sea surface temperatures

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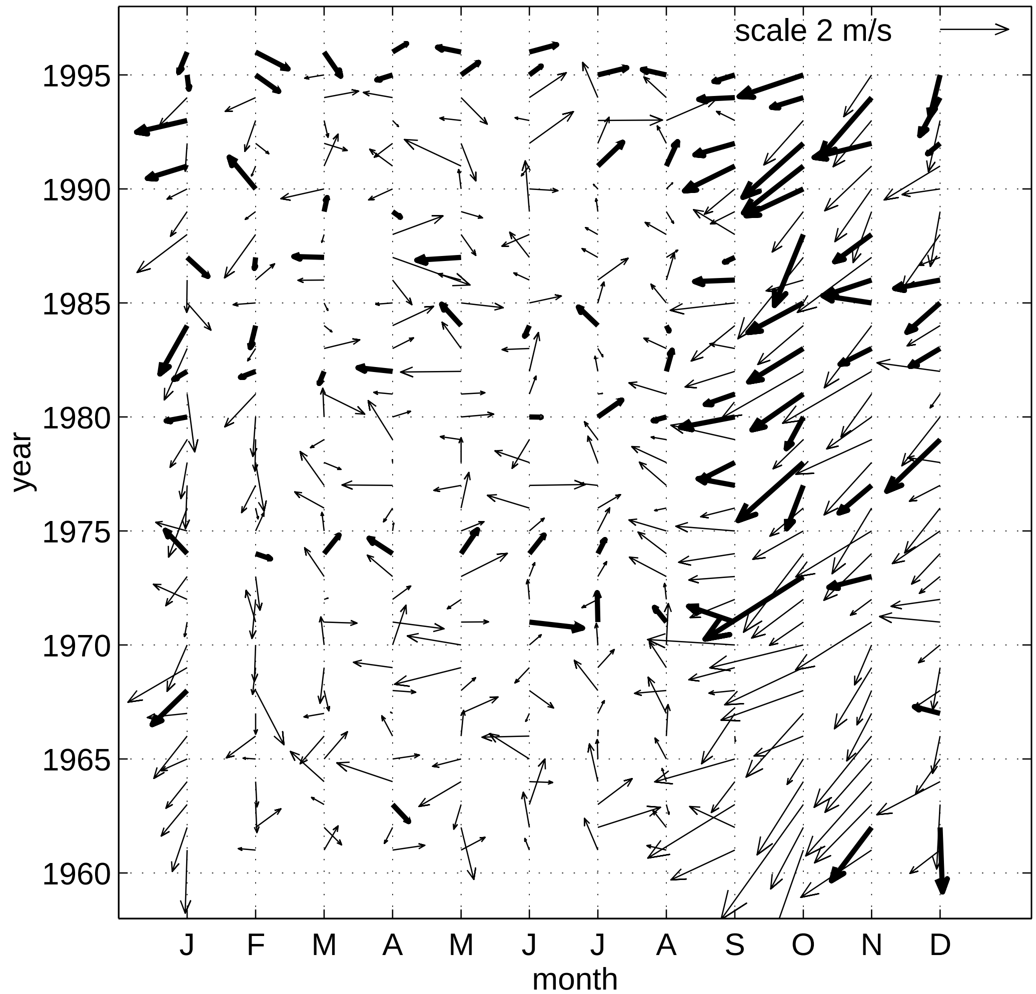


Fig. 2. Monthly mean wind vectors at Tampa, Florida. Bold vectors denote months red tide blooms were observed at the coast between Tampa and Naples. While few blooms occurred along this coast in the 1960's, major blooms were reported further north along the Gulf Coast.

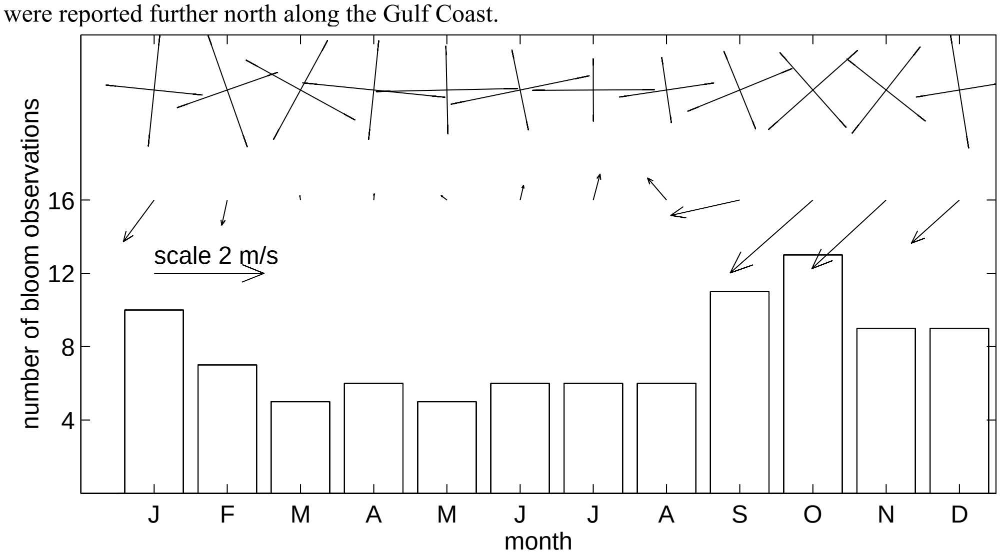


Fig. 3. 1961-1996 climatological summary of red tide blooms observed at the coast between Tampa and Naples (bottom), mean wind vector (middle) and principal axes of variance of wind vectors (top) at Tampa, Florida.

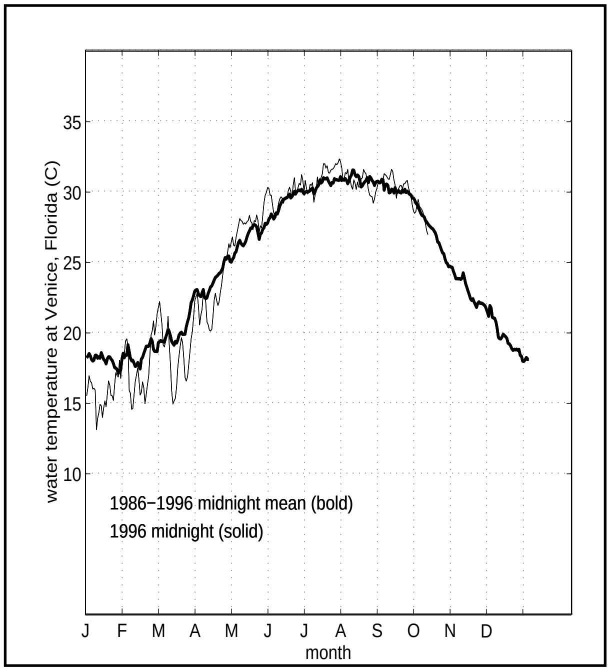


Fig. 4. Water temperature at Venice, Florida. Bold line denotes the 1986-1996 mean water temperature at midnight. Thin line denotes water temperature at midnight for 1996.

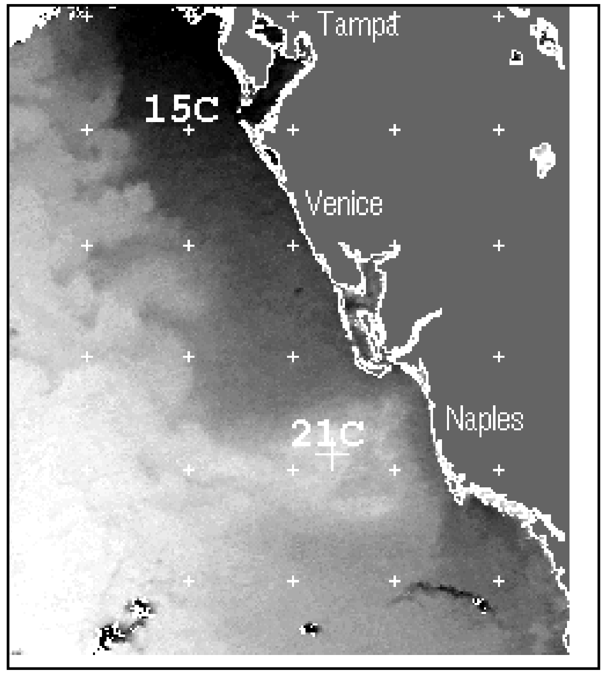


Fig. 5. Water temperature from satellite, 09Feb96, 1300 PM, showing 21C water near Naples. The severe winter bloom began in mid-February just north of Naples, suggesting a linkage with this type of feature.

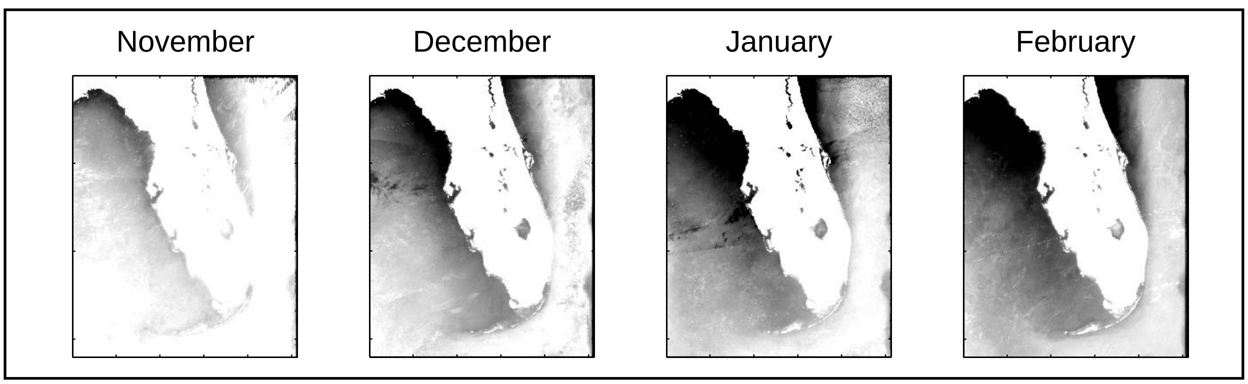


Fig. 6. 1989-1996 mean sea surface temperature (*SST*) by months. Gray scale is linear. Black denotes *SST* < 18$^{o}$C and white denotes *SST* > 26$^{o}$C.

(*SST*) are determined using standard equations [5]. The image maps for the winter are means of the 1989-1996 monthly composites of maximum *SST* at each image location (pixel) . The use of the maximum should indicate the optimal temperature for *G. breve* during the month.

## RESULTS

Between March and August, monthly mean winds are weak (Fig. 2). While the mean orientation is northward, the sub-monthly variabilities are anisotropic and oriented mostly east-west (Fig. 3). The variance in the winds is constant from fall through spring, although the mean direction and speed varies.

Few red tide blooms are observed between Tampa and Naples (Fig. 3). Blooms were less common at the coast in this region in the 1960's, than in the 1950's (unpublished data) or 1970's. Major blooms did occur in Florida in the 1960's outside this region.

Beginning in September, the winds strengthen and the observed number of blooms at the coast also rises, with both peaking in October. Through fall and early winter, wind speed and inshore water temperature decrease (Fig. 4), and bloom observations are less frequent. However the temperature reaches a minimum in January and February while the number of blooms reaches a minimum in the spring. The general pattern shows cold water reaches the maximum offshore and southward extent in February (Figs. 5 and 6).

## DISCUSSION

Seasonal wind and water temperature patterns may influence the variability of the number of bloom observations at the coast. Light winds in spring and summer may permit concentration of the organism offshore, particularly with its tendency toward positive phototaxis [2]. For each month between April and August, the primary axes of wind variabilities are oriented east-west. We hypothesize that predominately westward winds, persistent for 1-2 weeks, can transport red tide blooms inshore. Of blooms present in September, in half the years they were present onshore in the summer (Fig.2).In September, as wind speed strengthens, and water column destratifies, *G. breve* is distributed throughout the water column. At longer time scales, offshore winds would produce offshore transport of surface water. Strong winds may redistribute the organism through the water column, allowing high concentrations to remain nearshore through bottom return flow (upwelling-type events). Blooms present in the spring are generally those that have persisted from the previous fall.

Since *G. breve* prefers water temperatures between 16 and 27$^{o}$C [6], cool water temperature in the winter months may contribute to the reduced cell counts. As water temperatures on average are above 16 $^{o}$C (Fig. 4), temperature is unlikely to be the sole factor. In January 1996, the inshore water temperature was generally 3$^{o}$C cooler than the mean, with the bloom strongly reappearing in February when the temperature dropped to 15$^{o}$C (5$^{o}$C cooler than the mean). The peak cell counts of > $10^6$ cells/L at Venice occurred at the extremely warm period at February 28, when temperatures reached 22$^{o}$C. The possibility exists of a unique combination of events, an *SST* image on February 9 suggested a filament of warm water reaching nearshore between Venice and Naples, which may have reintroduced the bloom to the coast (Fig. 5). However, we do not have offshore cell counts to confirm that the bloom was found in this feature.

## CONCLUSIONS

Previous studies have noted that blooms initiate in the summer. The weak winds during summer allow concentration of the organism at the surface and the dominant east-west variability indicates periods of mild onshore winds that will produce surface drift onshore. The persistence of blooms through the fall in spite of strong offshore winds indicates more complex transport mechanisms, perhaps involving return flow (or upwelling) at the bottom. Winter temperatures probably discourage bloom growth, however additional offshore data will be critical in understanding the transport mechanisms of specific events, such as the winter 1996 bloom.

## ACKNOWLEDGEMENTS

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